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ASTRONOMY RESEARCH AT THE AEROSPACE CORPORATION

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Aerospace Corporation

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This report reviews the astronomy research carried out at The Aerospace Corporation during 1974. The report describes the activities of the San Fernando Observatory, the research in millimeter wave radio astronomy as well as the space astronomy research.

PRICES SUBJECT TO CHANGE

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PREFACE

Material for this report was contributed by Dr. E. E. Epstein,
Dr. E. B. Mayfield, Dr. D. L. McKenzie, Dr. H. R. Rugge and Dr. J. H.
Underwood.

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INTRODUCTION

Research in astronomy is carried out by groups in the Electronics Research Laboratory and the Space Physics Laboratory. Both of these organizations are components of the Laboratory Operations of The Aerospace Corporation which are managed by Dr. G. W. King.

I. ELECTRONICS RESEARCH LABORATORY

Personnel: Radio astronomy research is conducted at The Aerospace Corporation by Dr. Eugene E. Epstein, John W. Montgomery, Dr. John Mottmann (now at California State University, San Luis Obispo), Dr. Fred I. Shimabukuro, Julia D. White, and Dr. William J. Wilson (all on a part-time basis). Richard B. Pomphrey, a graduate student at the University of Florida, participated full-time as a guest investigator. The research effort is supported by Gerald G. Berry, Martin F. Bottjer, Howell B. Dyson, Elmer H. Erfurth, Robert D. Etcheverry, Will A. Garber, Walter A. Johnson, Howard E. King, Daniel L. McKenna, Tom T. Mori and Bert E. Seiver.

Instruments: A program of 3-mm wavelength continuum radio astronomy has continued using the 4.6-m radio telescope located in El Segundo. After over ten years of use, the 20-bit shaft angle encoders were overhauled and all of the electrical cables were replaced. A new feed-horn carriage and mounting bed for RF front-end components was installed in the antenna reflector back-up structure behind the Cassegrain focus; this carriage and bed can be partially pulled out (like a file drawer) for convenient access. The hot-load calibrator used with the continuum receiver has been modified to eliminate a small, but systematic, diurnal error. Also, to eliminate some moving parts, it has been altered by replacing a variable precision attenuator with an 8-dB directional coupler; the output of the hot load, as measured through the two ports of the coupler, provides the internal calibration signal. The temperatures of the hot load and the coupler are monitored regularly.

677 five-point Gaussian-fit observations (each observation represents 15 minutes of telescope time) of Jupiter and Venus obtained between May 1971 and April 1974 have been analyzed for the hour angle and declination half-power beamwidths of the 4.6-m antenna as a function of antenna attitude. No significant dependence of the beamwidths on antenna attitude was found for the range of attitudes used in normal observing (zenith distance $\leq 60^{\circ}$). However, the beam is not circularly symmetric; the half-power beamwidths in the E - W, NW - SE, N - S, and NE - SW, directions are, respectively, 179" $\pm$ 1", 184" $\pm$ 2", 194" $\pm$ 1", and 189" $\pm$ 2".

After a major effort, the 2-to 4-mm spectral line receiver has been completed for use with the 4.6-m radio telescope. Spectra were recorded on the very first attempt (on 30 August 1974). The superheterodyne receiver has a single sideband noise temperature of ~3000 K; it can be used in the frequency, load, or position switching observing modes. Two 64-channel filter receivers (1-MHz and 250-kHz resolution) are available and are coupled to a computer-controlled data processing system. This system controls the antenna and the receiver and allows real-time data processing by the observer.

Qualified investigators interested in utilizing the Aerospace radio astronomy facilities should contact Dr. Epstein.

A. Continuum Studies

As in previous years, the regular monitoring of several of the stronger variable radio sources has continued; frequent observations of the reference source DR21 have been included. Monthly observations of Jupiter,

Saturn, and, occasionally, Venus have also continued. The observing efforts were interrupted for two lengthy intervals in conjunction with installation of the spectral line receiver.

The discovery of the above-mentioned systematic calibration error has necessitated a time-consuming revision of prior data reduction and has interrupted the work of putting all non-solar data obtained since 1965 on a uniform calibration scale.

The 3.3-mm solar limb brightening measurement data taken during the 30 June 1973 total eclipse at Lake Rudolf in Kenya have been reduced. The solar limb was tracked at the appropriate contact point during the four eclipse encounters, such that there were four opportunities to measure the limb brightening. A parametric circularly symmetric solar flux model was used as a basis for estimating the brightness distribution. The results show that there is a limb brightening of about 20 percent, occurring within one half arc min of the limb, and the total limb brightening flux is less than two percent of the uniform solar disk flux. The limb brightening is that measured by a system whose resolution cell includes a large number of any inhomogeneous structures which may be present; hence the limb brightening function is smooth. The small amount of limb brightening, as compared to that predicted by currently accepted models of the spherically symmetric quiet solar atmosphere, reinforces the argument that the net effect of the non-homogeneous features in the solar atmosphere is limb darkening at the millimeter wavelengths.

B. Spectral Line Observations

In February 1974, the Caltech interferometer was used in collaboration with Neal Evans to measure the positions of a number of previously unidentified OH sources.

In April, 2.6-mm observations of galactic CO emission for comparison with HI observations were made with the NRAO 11-m antenna at Kitt Peak; this effort was in cooperation with C. Simonson and F. Kerr of the University of Maryland. During this same observing period, further observations of CO emission from interstellar dust clouds were obtained (in cooperation with A. Milman of the University of Maryland); the results showed that nearly every dust cloud had detectable CO emission.

In October, in cooperation with H. R. and J. R. Dickel (University of Illinois), detailed observations of CO emission around the HII regions NGC 6334, DR 21, NGC 7538, and W3 were made to determine the correlations between the CO, infrared, and optical features. The preliminary results suggest that the CO emission is generally correlated with the infrared radiation, but there are differences on a fine scale.

In November, studies of OCS were made at 48, 85, 97, and 109 GHz in cooperation with P. Goldsmith (University of California, Berkeley) to obtain detailed information about physical conditions in several interstellar molecular clouds. (The October and November observations were also made with the NRAO 11-m antenna.)

Obse vational programs which will be carried out with the Aerospace 4.6-m antenna include:

1) Studies of galactic CO emission and comparison with HI observations;

2) Studies of CO and HCN emission associated with selected HII regions;

3) CO observations of interstellar dust clouds;

4) Association of CO emission with galactic supernova remnants;

5) Correlation of CO and HCN emission with 1-mm continuum sources;

6) Studies of HCN and CO emission near 100-micron infrared sources;

7) Studies of CO, H_2CO, and CS emission in dust clouds; and

8) Searches for new interstellar molecules.

The majority of these programs are cooperative ones with observers from other institutions.

II. SPACE PHYSICS LABORATORY

The Space Physics Laboratory operates the Aerospace Corporation's San Fernando Observatory and also conducts astronomical observations at x-ray wavelengths using rockets and satellites. The activities of these groups are described as follows.

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A. SPACE ASTRONOMY PROJECT

Research programs on the solar atmosphere are being carried out by the Space Astronomy Project within the Space Physics Laboratory, using satellite and rocket-borne instrumentation.

Personnel: The x-ray and EUV research programs were carried out by Dr. N. G. Alexandropoulos, Dr. P. Landecker, Dr. D. L. McKenzie, Dr. H. R. Rugge, Dr. J. A. Vorpahl and Dr. J. H. Underwood. Dr. E. B. Mayfield of the San Fernando Observatory continued to be deeply involved in the S-056 Apollo Telescope Mount data reduction and analysis program. Technical support for the various projects has been provided by W. L. Brown, A. G. Harper, T. H. Higa, E. M. Irwin, D. A. Jones, D. A. Roux, G. E. Schacht, V. Stevens, R. L. Williams and R. M. Young.

Solar Research: Current solar research programs include: the analysis of high spatial resolution solar filtergrams obtained with the S-056 x-ray telescope on the Apollo Telescope Mount (ATM) on Skylab, analysis of a multi-spectrometer rocket x-ray and EUV payload launched during the Skylab mission, continued studies of coronal structure, relative abundances, active regions and flares using observations obtained with the x-ray crystal spectrometers flown on the OV1-10 and OV1-17 satellites and analysis of the UCSD hard x-ray burst detector and the GSFC x-ray and EUV spectroheliograph experiments on OSO-7. Developmental plans include a satellite x-ray spectroheliograph planned in conjunction with the Naval Research Laboratory, a potential x-ray-XUV payload for a future Space Shuttle Mission in conjunction with

Marshall Space Flight Center and American Science and Engineering, and an x-ray polarimeter being considered for the Solar Maximum Mission.

Studies of Coronal Abundances and Structure: Analyses of the x-ray spectra in the 3 to 26 A region, obtained from the OV1-10 and OV1-17 satellites, have continued. Models of coronal emission measure versus temperature have been constructed for a variety of solar activity conditions. The appropriate emission measure functions were used in obtaining relative coronal abundances. A recent re-analysis of the iron relative abundance has been performed taking into account the very important contributions from cascades from highly excited levels of Fe XVII; an analysis not previously performed because of the lack of theoretical information on the decay scheme of the complex Fe XVII atom. The relative coronal abundances obtained from this analysis are compared to several other solar and cosmic abundances obtained by other researchers in Table I.

TABLE 1

Comparison of Relative Abundances

Element	Active Region Space Physics Lab	Abundance (x10⁶) Transition Region Withbroe	Abundance (x10⁶) Transition Region Dupree	Photospheric Withbroe	Solar System Cameron
N	90	89	150	115	117
O	700	450	595	676	676
Ne	54	28	27	-	108
Na	1.7	2.3	1.9	1.7	1.9
Mg	30	35	30	35	33
Al	2.5	2.3	3.5	2.5	2.7
Si	35*	35*	35*	35	31.6
S	9	11	20	16	16
Ar	6	4.5	-	-	3.7
Fe	26	35	20	25[†]	26

[†] In a recent analysis, Smith and Whaling find a value of 25×10^{-6} for the iron abundance, in agreement with the earlier result of Withbroe.

* The coronal abundance values have been normalized relative to the silicon abundance, which was assumed to be 35×10^{-6}.

Solar X-Ray Burst Studies: Studies of solar x-ray bursts are being carried out by McKenzie using data from two instruments on OSO-7. The UCSD wheel experiment, consisting of a proportional counter and an actively shielded scintillator, and the Ross balanced filter pairs from the Goddard Space Flight Center pointed section are being used.

The height of hard x-ray burst origin may be studied by observing bursts partially occulted by the limb. The study concentrates on eight selected OSO-7 bursts with strong emission at low x-ray energies (~10 keV) but no H-alpha emission as probable over-the-limb flares. A lack of hard nonthermal radiation from these bursts would indicate that the hard x-rays originate in the lower chromosphere, as some current models suggest. However, although the selected bursts had somewhat steeper spectra (more rapid falloff with increasing photon energy) than average, all had a readily detectable nonthermal emission component. Thus McKenzie concludes that an appreciable part of the hard x-ray emission occurs in the lower corona.

Models of hard x-ray bursts almost invariably assume that the x-ray emitting electrons are traveling through the solar atmosphere as a beam or with an anisotropic pitch angle distribution with respect to the local magnetic field. Such beaming results in anisotropic x-ray emission. If, as is often assumed, the electrons move principally perpendicular to the solar surface we should see more hard x-ray emission from flares near the limb than from disc center flares. McKenzie has searched for this effect by studying over one hundred hard x-ray bursts observed by the UCSD instrument on OSO-7. The emission at 20-30 keV is normalized

by dividing the emission of 5 keV, which arises from a Maxwellian distribution of electron velocities and a isotropic. Plotting this ratio against the burst longitude as determined by H-alpha observations, no correlation is found. This result rules out the models in which the energetic electrons beam inward normal to the solar surface but does not preclude all anisotropic electron velocity distributions.

A study of solar flare iron line emission around 1.9 A using the UCSD and Goddard experiments on OSO-7 is under way. The Goddard Ross filter measurements complement the UCSD proportional counter data by providing improved energy resolution at the line energy. The purpose of the study is to determine the line/continuum ratio at 1.9 A and to have a measure of the ratio of the iron and helium abundances in the solar corona. Three flares occurring in October-November, 1972, have been selected for study. Detailed studies of the two instruments are being carried out to facilitate the analysis.

Solar Rocket Spectroscopic Payload: On January 22, 1974 a solar rocket payload was launched from White Sands Missile Range at 1645 UT. The objectives of the payload were to carry out high resolution spatial and spectral measurements of a coronal active region in x-ray and EUV spectral regions at the same time as high spatial resolution measurements were being made of the same active region by the Apollo Telescope Mount experiments flown on Skylab; and to derive a physical model of the conditions in the coronal active regions on the basis of data obtained from the rocket instrumentation and several of the Apollo Telescope Mount experiments. The instrumentation, which appears to have functioned normally, consisted of two collimated x-ray Bragg crystal spectrometers, two collimated grazing incidence EUV spectrometers, an x-ray telescope/filter wheel-camera, and a collimated proportional counter

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Table 2. Major Rocket Instrument Parameters

Instrument	Wavelength Range, Å	Resolution	Effective Aperture Size, cm²	Spatial Resolution on Solar Disk
RAP crystal spectrometer	7.8-25.5	$\lambda/\Delta\lambda \cong 5 \times 10^2$ at 20 Å	51.6	2.1 arc min × 1.4 arc min (along direction of dispersion)
ADP crystal spectrometer	3.2-10.4	$\lambda/\Delta\lambda = 10^3$ at 9 Å	51.6	Same as above
Short λ XUV grating spectrometer	20-220	$\lambda/\Delta\lambda = 10^2$ at 100 Å	5.2	Same as above
Long λ XUV grating spectrometer	128-400	$\lambda/\Delta\lambda = 2.5 \times 10^2$ at 400 Å	8.7	Same as above
X-ray telescope/filter-wheel-camera	5-60	$\Delta\lambda = 10$ Å; 8 filters of 5 materials of varying thickness	1.6	~20 arc sec
Proportional counter	2-10	8 channels; $\lambda/\Delta\lambda = 10$	1.27	2.1 arc min × 1.4 arc min (along direction of dispersion)

experiment. Preliminary results from the crystal spectrometers indicate the active region studied emitted radiation most strongly in the lines of O VII with weaker emission from O VIII. Lines of Fe XVII and Ne IX were very weak indicating an effective temperature of $\sim 2.0 \times 10^{6}$ °K. This region was photographed by the ATM S-056 experiment at the time of the rocket measurement. It had no outstanding features. However, four hours later the region had developed a large number of complex loop structures interconnecting various sections of the active region with other nearby active regions. Analyses of all of this data is continuing. Table 2 summarizes the rocket's major instrumental parameters.

Analysis of Skylab S-056 Experiment Data

The Skylab-ATM S-056 experiment was a glancing incidence x-ray telescope which obtained approximately 20,000 high resolution photographs of the sun in the soft x-ray region. In addition, a proportional counter-pulse height analyzer system (X-REA) obtained full sun spectra.

Careful study of the x-ray pictures, together with the X-REA data and other supporting data such as magnetograms, has given a new and exciting insight into such phenomena as the structure of the quiet corona and "coronal holes", the morphology, development and physics of active regions, the development of flares in the corona, and so on. In addition, several new and unsuspected phenomena have been observed.

Preliminary results indicate that over an active region, the coronal structure develops as a series of filaments or loops which straddle the neutral line of the longitudinal magnetic field. This structure establishes itself at an early stage in the development of the region. Although the

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structure evolves and remains stable during the growth of the region, individual loops brighten and fade away on a time scale of the order of days. The stability of the individual loops is an interesting problem in magneto-hydrodynamics. At least one case has been observed of bright points, at the opposite ends of a loop, oscillating in brightness in antiphase. This phenomenon appears to be due to a disturbance (Alfven or sound wave) propagating through the loop at a speed of about 200 km/sec. We have also noted the development of a large loop on the limb in a time of about 10 minutes. In this case, material appeared to be projected from one end of the loop to the other.

Loop structures seem to play an important role in other solar phenomena. We frequently observe large loops interconnecting regions far apart on the solar surface. It appears that particles may be guided along these large structures to produce simultaneous radio bursts in these widely separated regions. Flares often begin as a small bright loop or filamentary structure which later brightens further and disrupts.

Study of the photographs has progressed to the point where it is possible to measure the temperature and density in particular coronal regions. These measurements should help provide the answer to a number of intriguing questions in solar physics.

SAN FERNANDO OBSERVATORY

Personnel: Research in solar physics at the San Fernando Observatory is conducted by Dr. Gary A. Chapman, Dr. Edward N. Frazier, Dr. Thomas J. Janssens, Dr. Earle B. Mayfield and Mr. Dale Vrabec. Mr. Kennon P. White, III and Mr. Edward J. Rhodes, Jr. are graduate students at UCLA and part-time members of the staff as is Mr. David K. Lynch who is a graduate student at the University of Texas. Mr. Neal K. Baker works part time while he is a graduate student at Pennsylvania State University. In May Dr. Janssens transferred to another group at Aerospace. Dr. Richard G. Teske from the University of Michigan spent the year at the Observatory as an academic visitor on sabbatical leave. Theoretical work in solar physics was done by other members of the technical staff at Aerospace. These included Dr. Yam Tsi Chiu, Dr. Michael Schulz and Dr. Rudolf X. Meyer. The support group of the Observatory are Robert J. Maulfair, William E. Mott, Harold Strawhorn and Sheldon B. Wiemokly. Barbara Hatfield was a student observer from Harvey Mudd College during the summer of 1974.

Instruments: Instruments in use at the Observatory during the year were a 61 cm telescope and spectroheliograph, a 30 cm spar telescope with Ca II K and Hα filters, a 15 cm filter telescope used with a videomagnetograph, two 15 cm telescopes for whole disk white light and Hα observations and a 15 cm filter telescope for large image scale time-lapse data. In addition, two radio telescopes for total emission studies at 3 and 10 cm wavelength and a Mg b line filter and extreme limb photometer fed by the 61 cm telescope were used. These were operated during all or part of the year and provided

extensive data. Details of these instruments have been previously published.

The 61 cm telescope and spectroheliograph system is designed for primary image investigations, spectroscopy and magnetic and velocity field observations. This telescope also functions as the spar mount for the 30 cm Ca II K and Hα filter telescope. These instruments operate independently but can be collimated for simultaneous observations of a single region. Both instruments are controlled by a small digital computer which permits programming a wide range of operating modes. Data are obtained on film and can be digitized and stored on magnetic tape. Video displays are provided for the Ca and Hα images.

The videomagnetograph is used to obtain real-time magnetic field data which can be displayed as a magnetogram or stored on magnetic tape. This instrument uses a very narrow bandpass filter centered on the Fe I line at 5374A, an electro-optic quarter-wave plate and video camera to obtain filtergrams of the polarized components of this line. Operation of this system and reduction of the data is done by a small computer which provides, in addition to magnetograms, analysis of the fields such as total flux, centroids, etc.

Visual observations and whole disk photographs in white light and Hα are made routinely and monitoring of radio emission at 3 and 10 cm is done for investigations of active regions. Qualified investigators interested in utilizing the facilities at the San Fernando Observatory should contact Dr. E. B. Mayfield.

Research: The past year from July 1973 through June, 1974, was very productive for the Observatory and 11 papers were published by the staff. Invited papers were given by Dr. Frazier and Mr. Vrabec at the IAU meetings in Australia. Progress in research by the graduate students was also good and Mr. Lynch should complete his dissertation during the next year. Support to the Skylab/Apollo Telescope Mount program was a significant accomplishment during the year. A joint investigation with the S-056 experiment of the ATM was initiated and will continue during next year. This will be based on analysis of x-ray filtergrams obtained by S-056 and magnetograms and other data from the Observatory recorded during the Skylab mission.

Magnetic and Velocity Fields: Observations made by Vrabec have established that small moving magnetic features (MMF's) occur near sunspots. These MMF's exhibit a highly ordered pattern of movement directly related to the associated sunspot. The observations are consistent with the concept of magnetic flux outflow (MFO), a process whereby net magnetic flux of the same polarity as the sunspot is transferred from a decaying sunspot to the surrounding magnetic network. Small magnetic flux concentrations are apparently convected outward by a velocity cell centered on the sunspot. Doppler spectroheliograms have provided evidence for such systematic outward velocities extending as far as 10,000 to 20,000 km beyond the outer edge of the penumbra of some sunspots, which is comparable to the extent of MFO. While MFO is best observed by means of time-lapse pictures of the magnetic fields, it is also seen on individual magnetograms by features that resemble moats around only those sunspots where MFO is present. Examples of magnetic features streaming toward and into rapidly forming sunspots provide

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evidence for the occurrence of magnetic flux inflow (MFI) associated with the growth phase of sunspot development. It is, therefore, likely that MFI and MFO are basic aspects of the evolutionary development of sunspots.

Magnetic flux inflow (MFI) is a dynamic, sunspot-associated phenomenon manifested by moving magnetic features that stream toward the sunspot along paths converging upon it. In contrast to MFO, many of the MMF's involved in MFI, but not all, are pores easily observed in integrated light. Some of the MMF's, including pores, move directly into the umbra of the sunspot and coalesce with it. It is almost a certainty that MFI is associated with the growth phase of sunspot development and with the emergence of new magnetic flux at the photospheric surface.

Velocity spectroheliograms were made by Teske in the wings of Ca I λ6103, using an image scale of 60 micrometers per arc-sec on the sun in order to examine this problem in detail. An entrance slit width of 1.0 arc-sec was used. The two exit slits, of width 60 mA in the spectrograph focal plane, were centered 60 mA from the core of the line. The solar image was scanned once per spectroheliogram at a rate of about 5.4 arc-sec per second of time. Two pairs of spectroheliograms obtained during superior and uniform seeing conditions were selected for analysis. On them, photospheric structures of size approximately one arc-sec or smaller were visible.

Two dimensional autocorrelation functions of photospheric velocities observed in the Ca I λ6103 line have central peaks whose widths strongly suggest the presence of velocity elements of size about 5 arc-sec.

Two dimensional power spectral density distributions of the velocity

fluctuations do not display strong power concentrations at wavenumbers appropriate to that 'classical' size of oscillatory elements. Were these cells indeed characterized by a fairly uniform $k_h - (k_x^2 + k_y^2)^{1/2}$ and were they spatially periodic, they should be clearly seen in the two dimensional power spectra, whatever the values of k_x and k_y for each cell, as a circularly-symmetric ridge. Because the expected ridge is absent, Teske infers that the velocity cells tend to be spatially aperiooic; variations in their size and randomness in their distribution on the photosphere has blurred their appearance in power spectra from velocity snapshots of the sort used here.

The departure from azimuthal symmetry of two dimensional AC functions and their two dimensional Fourier transforms is not strong, and the departure decreases as the data sample area increases. Departures from azimuthal symmetry are entirely a matter of data sample size. Thus one dimensional techniques are useful and proper so long as the data sample is large.

Teske concludes that the failure of one dimensional sampling techniques to portray the spatial power peak for 'classical' 5-min. oscillations is not due to the use of one dimensional analysis. Rather it is perhaps inherent in the use of power spectrum techniques to characterize a quasi-random distribution of velocity cells.

Lynch began a separate but related study involving the photospheric velocity field in non-sunspot regions. This involved photographically separating the slowly varying component of the velocity field from the oscillatory component. If two velocitygrams are taken 2.5 minutes apart and are then added, they produce a velocitygram showing only the slowly varying fields. If they are subtracted, they show only the oscillatory field. Except for

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secular changes in the velocity field in 2.5 minutes (which are small) the two doubly added/subtracted pictures are independent of one another. However, since both velocitygrams are derived from the same original data, effects of seeing, image motion, etc. are common to both pictures. Thus any difference between two doubly subtracted images must be a real solar effect.

In particular, the most obvious difference between an added picture (primarily granulation velocities) and a subtracted picture (mostly oscillatory velocity) is the size of the elements. Specifically oscillatory elements are larger than the slowly varying elements. It is also observed that the oscillations have a higher amplitude than do the granulation. Direct calculation agrees with this and confirms that the oscillations have 30% greater velocity amplitude than the granulation.

The statistical analysis of this data is continuing. It appears that the power spectrum analysis can be of greater use in interpreting the data if one makes certain assumptions about the nature of the process. Indeed, one can verify or reject certain ideas about the power nature of the generation process by constructing models of the data and testing them against the observed statistical properties of the solar photospheric velocity field.

During the year Lynch continued to reduce the data taken during the summer of 1973 at the Observatory. Magnetic non-sunspot regions were the object of this research. It was found that the small network elements of mean flux or 2×10^{19} Maxwells disperse along the boundaries of the supergranulation. This linear diffusion occurs continually with a horizontal velocity of 0.25 ±0.15 km/sec. The elements disperse for about 2-3 days until they are no longer

recognizable as the same feature. The flux appears to be conserved as the elements fragment.

A new effect concerning the fine structure of magnetic fields has been discovered by Frazier and partially analyzed by him. This effect is an error in the measured velocity fields caused by extremely high magnetic field strengths. These high field strengths have been shown by others to exceed one kilogauss and could even exceed two kilogauss. Such high field strengths imply, of course, that the magnetic features are very small, less than one arc-sec. This velocity error can be calculated from a detailed model of magnetic fine structure and compared with observational data. Adjustment of the model to fit the data then provides a unique solution to the magnetic fine structure despite the fact that it cannot be observed directly.

In May 1974, Frazier used the McMath telescope at Kitt Peak National Observatory to obtain the necessary data to complete this modeling. The observations were successful and early results indicate that the data are excellent. Reduction and analysis of these data is partially complete.

Observations of solar magnetic fields were made at the San Fernando Observatory simultaneously with the x-ray observations on the Skylab/Apollo Telescope Mount. These data have been compared by Meyer and Mayfield with detailed calculations based on a force-free field model.

Underlying the comparison with the x-ray data is the hypothesis that the observed x-ray filament coincides with a magnetic field line belonging to a force-free field configuration or with a more or less localized bundle of such lines. The photographic recording of the filament can then be compared with

the projection along the line of sight of the computed magnetic field lines of the model.

Contrary to potential field solutions, electric currents are included in the force-free field model. The currents are assumed to be directed either parallel or antiparallel to the local magnetic field, resulting in the condition curl H = αH. The coefficient α is assumed to be constant and is positive if current and field are parallel, negative if antiparallel. Arguments in support of these assumptions for fields in the chromosphere and lower corona have been discussed elsewhere.

The force-free field model used in this paper is axially symmetric and represents the lowest order term in an expansion in terms of spherical Bessel functions and Gegenbauer polynomials of the force-free field solutions. The solutions resemble those for a magnetic dipole, but the field lines exhibit a characteristic twist, produced by the current flowing along the lines. Good agreement was obtained between the experimentally observed x-ray features and computed magnetic field lines.

Stellar Photography, Solar Oblateness and Radio Emission: In astronomy, the question frequently arises, "How faint a star can a specified telescope detect photographically?" This can be answered either by inference from empirical data on the magnitudes of the faintest stars that have been photo- raphed with existing telescopes of various types and sizes or, alternatively, calculated from basic principles. Using the latter approach, an analysis developed by Vrabec successfully predicts the empirically achieved limiting magnitudes of stars reached with telescopes ranging from the 20-inch F/1

Baker-Nunn satellite tracking cameras to the 200-inch Hale telescope at Mount Palomar. The formulas that are derived can be used to calculate the threshold detection performance of any telescope, given basic data on the optical system, tracking accuracy, photographic emulsion used, and conditions of observation such as sky brightness and "seeing."

In a recent paper by Dicke evidence has been presented for a new solar fluctuation having a period of 25 days. Chapman and Ingersoll have prepared a paper showing that photospheric faculae can explain the 25-day period of this fluctuation. This study is connected with the search for solar oblateness and the role that radiation emitted by solar faculae at the limb plays in contributing to the apparent oblateness of the sun.

Chapman and Ingersoll find that the observing pattern used by Dicke at Princeton, because of its irregular nature, causes noise spikes to appear in the facular power spectrum and greatly alters the appearance of its lagged autocorrelation function. The period of recurrence is shortened from 27.2 to 26.0 days, close to the 25.6-day recurrence period determined here for the oblateness residuals. Further, the Princeton observing pattern caused the full-rotation peaks in the facular autocorrelation to become doubled and obscures the half-rotation peaks, much like the oblateness autocorrelation. Thus the difference between the 25-day period of this fluctuation and the 27.5-day period of the facular autocorrelation is probably not meaningful and may be caused by the small size, short length, and irregular pattern of the Princeton data record.

New analysis considering data from all 64 days on which observations were made, and based on the assumption that both the observed oblateness signal and the facular signal are subject to error have been made. Chapman and Ingersoll find that faculae account for at least 1/3 to 1/2 of the observed excess oblateness, depending on whether 48 days or 64 days are used in the analysis. Moreover, faculae may account for all of the observed excess oblateness provided the facular error is sufficiently large. Thus faculae cannot be excluded as the major source of Dicke and Goldenberg's 1966 oblateness signal.

Most of the published theories of solar flares have been based on the presumption that the magnetic field of an active region is the source of energy for a flare. Although the exact process of field annihilation is not certain, it is believed that the conversion occurs at the neutral line or sheet separating fields of the opposite polarity. The principal difficulty for these theories as Parker showed, some years ago, is the excessive time required for the process to occur. Whereas flares are observed to reach flash phase in typically 10^2 to 10^3 sec, calculations yield times of 10^5 sec or longer to provide the 10^{32} ergs expected to be released by a major flare. Despite this difficulty, the premise is regarded as correct and subsequent work has examined various models to identify a rapid mode of field diffusion and annihilation. Recent theoretical work based on magnetohydrodynamic models has been successful in identifying processes of field annihilation which are sufficiently fast and compatible with experimental observations.

A study by Mayfield, White and Shimabukuro based on analyses of extensive observations of solar emission at 3.3-mm wavelength obtained

with the Aerospace radio telescope. These data cover the years 1967 through 1972 and, with a few missing periods, provide a continuous record of solar emission. Flare data for the same period, obtained from Solar Geophysical Data published by the National Oceanic and Atmospheric Administration, have been compared with the radio data. These results show a close association between regions of enhanced 3.3-mm radio emission and flares and statistical evidence for flare occurrence proportional to enhancement for importance 1N and 1B flares. The heating at millimeter wavelengths is observed to occur about 24 hours prior to flare onset and to be near the neutral magnetic field region. This is interpreted as heating by electric currents of a neutral sheet in the chromosphere separating fields of the opposite polarity.

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The Laboratory Operations of The Aerospace Corporation is conducting experimental and theoretical investigations necessary for the evaluation and application of scientific advances to new military concepts and systems. Versatility and flexibility have been developed to a high degree by the laboratory personnel in dealing with the many problems encountered in the nation's rapidly developing space and missile systems. Expertise in the latest scientific developments is vital to the accomplishment of tasks related to these problems. The laboratories that contribute to this research are:

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